Training Script for GOES-R Fog/Low Stratus Products

1. In preparation for the launch of GOES-R with the Advanced Baseline Imager (ABI), new products are being developed and tested so that forecasters will understand the products as soon as the launch occurs. The new GOES-R Fog/Low Stratus detection and thickness products have been developed by Mike Pavolonis (NOAA/NESDIS) and Corey Calvert (UW-CIMSS).

2. Currently scheduled to launch in March 2016, the ABI on GOES-R has greater spectral and spatial resolution than the present GOES Imager. In addition, scanning strategies will allow for greater routine temporal resolution. While the GOES-R fog/low cloud algorithms were designed to take advantage of the new capabilities offered by GOES-R, they were also designed to be backwards compatible such that it can be applied to the current GOES system and polar orbiting instruments like MODIS, which has better spatial resolution than GOES-R will have.

3. Fog and Low Stratus has a great impact on aviation. It is therefore appropriate to gear the FLS algorithm to the aviation community. The GOES-R FLS detection product identifies the probability that a given satellite pixel contains IFR (Instrument Flight Rule), or lower, conditions defined as having a cloud ceiling below 1000 feet above ground level or surface visibility less than 3 statute miles.

4. GOES-R products detect events that models cannot predict (because of resolution issues) and determine the spatial extent more accurately than can occur with surface observations; The GOES-R Fog/Low stratus product can be used to issue TAFs (Terminal Area Forecasts), generate G-AIRMETs and help build Sky Grids. The GOES-R FLS thickness product can also be used to estimate the dissipation time, after sunrise, of radiation fog events. In other words, you can assess hazards and use the product for day-to-day operations.

5. Traditional Fog/Low Stratus products have several limitations. GOES-R products are designed to mitigate these limitations.

6. The traditional brightness temperature difference between the near infrared (3.9 microns) and the window channel (near 11 microns) exploits the emissivity differences in water clouds that exist at those two wavelengths. One of the main limitations in the traditional BTD products arises when multiple cloud layers exist – if the satellite cannot view the low clouds because a higher cloud blocks the view, detection is impossible. Solar reflection during the day also changes the brightness temperature difference signal, and that complicates the interpretation of the field. Another important limitation is that the traditional brightness temperature difference does not differentiate between elevated stratus clouds (that are not hazardous) and low stratus clouds (that are hazardous). This makes it difficult to obtain an accurate depiction of hazardous areas from an aviation standpoint. As an example, we will consider two regions with similar enhancements – that is, where the difference between the 3.9 and 11 micron brightness temperatures is similar.

7. The observation at Corpus Christi TX shows a surface visibility of 3 miles and a cloud ceiling of 600 feet. These observations are consistent with IFR rules. The radiosonde from Corpus Christi,
TX (Frame 2) shows near-surface saturation that is consistent with the observations. This indicates that the cloud is located within the isothermal or inversion layer close to the surface.

8. Western Pennsylvania has a brightness temperature difference signal that is similar to that over Texas. However, the surface station at Pittsburgh, PA reported a visibility of 10 miles and a cloud ceiling height of 4700 feet. Thus, two similar brightness temperature difference signals are associated with very different aviation weather conditions. The sounding from Pittsburgh, PA (Frame 2) shows an elevated saturated layer, again consistent with the observation from the surface station of a cloud ceiling of ~4700 ft. This elevated cloud in Pittsburgh has roughly the same brightness temperature difference signal as the low cloud from Corpus Christi, thus making it difficult to differentiate the hazardous fog/low stratus clouds from the non-hazardous stratus clouds using the 11-3.9 micron brightness temperature difference alone. Vertical profiles such as this help to differentiate between the two, but they are very limited in time and in space.

9. The Traditional GOES low cloud base product (developed by Gary Ellrod) has limitations that mirror those in the BTD product upon which it is based. There are frequent misclassifications of areas with ceilings < 1000 feet, and, like the traditional BTD product (Frame 2), the product yields no cloud base information in regions where high or middle clouds are present. The GOES-R Fog/Low Stratus product (Frame 3) was designed to improve upon the traditional brightness temperature difference product. Unlike the traditional BTD product, it provides a coherent signal both day and night. It provides a signal even when multiple cloud layers are present, and it shows improved skill in detecting shallow fog layers and the overall presence of IFR conditions. Note here, for example, that the GOES-R IFR Probability field is correctly ignoring the Brightness Temperature Difference over Pittsburgh, where visibility obstructions are not present, and correctly believing the Brightness Temperature Difference signal over Corpus Christi, where visibility obstructions are present. The GOES-R Fog/Low Stratus products were designed to be backward compatible to present GOES and MODIS technology. Certainly when the ABI is broadcasting data, ABI improvements in spatial, spectral and temporal resolution will mean more accurate fog/low stratus observations. Using only the GOES-13 – GOES-15 Imager data is still an improvement over the simple traditional brightness temperature difference.

10. The GOES-R Fog/Low Stratus product can be displayed in both AWIPS-I and in AWIPS-II, however, the system must be tweaked before the products can be displayed. These websites detail what must be done in order to gain access to the GOES-R FLS products. Once the updates and configurations are completed the products can be loaded as shown in the following slides. The GOES-R FLS products (Frame 2) applied to GOES East and West are found under the ‘SSEC’ menu on the main AWIPS screen. Clicking on it should reveal a section called ‘GOES-R AWG for GOES’; AWG stands for Algorithm Working Group, a consortium that is developing the new products to be used with GOES-R. In the ‘GOES-R AWG for GOES’ section there is a series of menus. Click on the menu named ‘4-km Resolution-CONUS-GEOCAT’. (GEOCAT stands for GEOstationary Cloud Algorithm Test-bed). The products in the ‘4-km Resolution CONUS-GEOCAT’ menu (Frame 3) include: Cloud Thickness (in feet), IFR Probability (in %), LIFR Probability (in %) and Cloud-Top Phase. These products are created from GOES-East data and from GOES-West data (fused with Rapid Refresh model information as explained later in this
training module). Only (Frame 4) the IFR Probability and Cloud Thickness products are discussed in this training module. That is to say, training for Low IFR and Cloud Phase is not included here. GOES-R FLS products applied to MODIS imagery (Frame 5) can also be requested. These products reflect the higher 1km spatial resolution of MODIS imagery, but are available less frequently. These data can be found under the ‘MODIS Products’ section of the main ‘SSEC’ menu. Clicking on the ‘1-km Resolution – CONUS’ menu will bring up two more menus called ‘Vol Ash Products’ and ‘GEOCAT’. Clicking on the ‘GEOCAT’ menu will display the 4 GOES-R Fog/Low Stratus products: MODIS Cloud Thickness; MODIS IFR Probability; MODIS LIFR Probability and MODIS Cloud Top Phase. Again, these are all at 1-km resolution. The sub-tabs (Frame 6) that must be clicked through to get the MODIS data to display are displayed on this screen. Again, these are all under the SSEC Menu, in the MODIS Products section. There is a ‘1-km Resolution CONUS’ menu that includes a ‘GEOCAT’ menu that then includes the 4 GOES-R Fog/Low Stratus products. As with (Frame 7) the GOES-based products, the MODIS products that are discussed in this training include IFR Probability and Cloud Thickness only. Frames 8-10 are a repeat of Frames 5-7 (Sorry about that!). Then Frame 11 starts (ending with Frame 16) where to find GOES-R FLS under the AWIPS-2 ‘Satellite’ menu. Satellite, then CIMSS GOES Products (for GOES-based GOES-R FLS – there are East, West and AK sectors) or CIMSS MODIS Products (for MODIS-based GOES-R FLS – there are CONUS and AK sectors).

11. The theoretical basis for the Fog/Low Stratus product is described next. The GOES-R FLS products (Frame 2) use data from several of the Imager channels – including the visible during the day. For geostationary products only, data from the previous time are used as well to maintain temporal continuity. Unlike the traditional brightness temperature difference, which uses only the difference between two satellite channels, the GOES-R Fog/Low Stratus products are data fusion products. Satellite data are fused with other ancillary data using a Naïve Bayesian Model. The ancillary data includes a digital elevation map, surface type and surface emissivity (these are static datasets), daily sea surface temperature and snow/ice cover maps, and modeled surface temperature and relative humidity data (as well as profiles) from the Rapid Refresh (over most of CONUS/Canada/Alaska) or the GFS (globally elsewhere). Surface observations are not directly used – but those observations do influence results because they have a large impact on the model fields. The combination of all these data yield the GOES-R Fog/Low Stratus products that are available in AWIPS. The total time it takes to produce the GOES-R FLS products once the satellite data is downloaded is only about 2-3 minutes.

12. The brightness temperature difference is mostly a yes/no field. In contrast, the GOES-R Fog/Low Stratus product is a quantitative estimate; it is presented as a probability that suggests how likely IFR conditions are to be present. In the image shown, the redder regions are where IFR conditions are most likely to be present. High likelihood of IFR (Frame 2) – that is, probabilities exceeding 75% – usually correspond well with surface observations. In these regions there is a strong likelihood of low clouds based on the satellite data, and also a strong likelihood of low clouds based on the model RH fields – meaning saturation is occurring less than 1000 feet off the surface in the forecast model. Surface observations will usually be consistent with IFR conditions. IFR probabilities between 45% and 75% (Frame 3) can occur with a combination of satellite and model predictors of IFR. Strong satellite indicators of fog/low stratus combined
with weak model indicators of fog/low stratus, OR moderate indicators of fog/low stratus from both predictors (satellite and model) OR strong indicators from the model predictors and weak indicators from the satellite predictor. In this probability range there is a relatively high confidence that IFR conditions are present. Surface observations will likely be consistent with IFR conditions. IFR probabilities between 20% and 45% (Frame 4) represent low confidence that IFR conditions are present. These probabilities arise when moderate and weak predictions of fog/low stratus occur. That is, when satellite predictions of IFR give moderate indicators of fog/low stratus and model predictors of IFR give weak indicators of fog/low stratus OR when satellite predictors are weak and model predictors are moderate. When the GOES-R IFR probabilities fall into this range a user should further monitor these areas with additional information (if present) to rule out or gain confidence on the presence of fog/low stratus. IFR probabilities of less than 20% (Frame 5) represent a very low confidence that IFR conditions are present. Surface observations rarely will verify IFR conditions. Both satellite and model predictors of fog/low stratus are weak in this case. Fog and low stratus are unlikely in these regions. Consider carefully that cirrus clouds (Frame 6) can change the IFR probabilities, as shown in this example. Both predictors – satellite and model – must give a strong indication of fog/low stratus for the highest probabilities, and that cannot happen if cirrus clouds are present, as in this case off the coast of Oregon. With time (Frame 7), you should be able to distinguish between regions where satellite-only data are being used (as in the River Valleys here in central Pennsylvania) and regions where model data are used only (southwest New York) and where both are used (northwest Pennsylvania). The other GOES-R FLS product included in this training module is the cloud thickness (Frame 8). This is calculated empirically and estimates the thickness, in feet, of the highest liquid cloud layer that is not overlain by higher clouds. That last caveat is important. Cloud thickness will only be available for single layer water clouds. Even when FLS is present, FLS cloud thicknesses will not be computed in areas such as under cirrus shields or convective thunderstorms. This product can be used to infer shallow fog layers and differentiate between thicker/thinner parts of clouds. The GOES-R cloud thicknesses can also be used to estimate the dissipation time of radiation fog after sunrise, which will be described in more detail later in this training.

13. These GOES-R Fog/Low Stratus products were validated using surface observations of ceiling and of visibility over CONUS. Validation used 12 days of data – one day from each month during a year – and included about 1100 GOES-East scenes. The critical success index (CSI) was calculated as a function of the GOES-R IFR probability and traditional BTD threshold. Bottom line is that the GOES-R product was determined to be about twice as skillful as the brightness temperature difference product at detecting hazardous IFR conditions — the maximum CSI for the GOES-R product was about twice the maximum CSI for the brightness temperature difference. In Frame 2, the same figure is shown for Alaska.

14. There are a few artifacts that may be noticed when using the GOES-R FLS products. One of them arises due to model boundaries. Model fields are used in this data fusion product. The higher resolution rapid refresh is used over North America. GFS data are used elsewhere globally. Not surprisingly, there is often a seam visible at the outer edge of the Rapid Refresh domain where
the model fields do not exactly mesh. For WFOs this should not be an issue but it may be for marine forecasts.

15. Another issue comes from a stray light correction that occurs at certain times of the year that causes the GOES-R IFR probabilities to be inflated artificially. However, it should be noted that this effect is more noticeable in the brightness temperature product (the ‘traditional’ Fog Product) than the GOES-R FLS products.

16. The GOES-R Fog/Low Stratus products change as day turns to night, and as night turns to day. The changes arise from different predictors (or different weights for the same predictors) being used to compute the product. The GOES-R Cloud Thickness product is unavailable during twilight conditions, but is available all night and during most of the day for single layer water clouds. Note that these features are apparent in the animation.

17. This training includes examples that are organized by geographic location that are specific for each region. However, it is highly recommended to look at examples from a variety of regions in order to get a broader training experience. Eastern Region Examples (Frame 2) cover the region in blue on this slide. Southern Region Examples (Frame 3) cover the region in purple on this slide. Central Region Examples (Frame 4) cover the tan region on this slide. Western Region Examples (Frame 5) cover the light blue-green region on this slide. Alaska Region Examples (Frame 6) cover Alaska. Note that OPC slides will be created soon. For the AWC (Aviation Weather Center) (Frame 7) examples are shown over CONUS.

18. This slide enumerates the different topics that are considered in the training. Fog and low stratus associated with synoptic scale cyclogenesis, radiation fog, advection fog and topographic influences. In addition, there are MODIS examples of river fog. MODIS’s 1-km resolution allows the thin fingers of fog in small river valleys to be detected, as opposed to GOES which has larger pixel sizes. Synoptic-scale weather (Frame 2) systems can produce IFR conditions over large areas in several different ways. Some areas may be affected by hazardous cloud ceilings from low stratus clouds while others may have reduced visibilities due to heavy rain and thunderstorm activity. In both cases, satellite data alone would not help to detect IFR conditions; model data becomes very important. Advection fog (Frame 3) commonly occurs over the cool waters off the Pacific and N Atlantic coasts of the U.S and the Great Lakes. Large areas of advection fog are also common in the winter/spring as warm air moves over snow/ice, or as weather systems traverse the country. The GOES-R FLS products can help determine the extent of the hazardous FLS areas as they advect over land/water. Visibilities can vary considerably in areas where advection fog and stratus occur. Radiation fog (Frame 4) poses a large hazard for transportation (including aviation) by drastically reducing visibility on large and small scales. Visibility can change rapidly over small horizontal distances. The GOES-R Fog algorithms show where fog is developing (IFR probabilities will slowly increase). Radiation fog can be tricky to accurately detect in its early stages because it usually starts out thin – undetectable by satellite – and thickens with time. Although satellites can detect the fog once it is thick enough, the combination of satellite with modeled RH data offers a way to amplify weak satellite signals to detect the early formation of radiation fog well before the traditional BTD product can detect it. Clouds can cause low surface visibilities in mountains where the higher elevations cause land and cloud to meet. (Frame 5) Surface stations are rare in higher terrain,
however, so observation/detection of Fog/Low Stratus are difficult. GOES-R IFR Probabilities can be used to determine hazardous conditions where mountains rise into clouds. Mountain obscuration can be very dangerous in mountainous areas: Alaska, the mountain West and the Appalachians.

19. This is an example of a northeast US Cyclone and the IFR probabilities that accompany it. The GOES-R product predicts IFR probabilities even when multiple clouds layers are present (multiple cloud layers that mean the traditional brightness temperature difference product will not work). The GOES-R cloud thickness product is only available when single boundary layer clouds are present under non-twilight conditions. These (Frame 2) figures include the GOES-R IFR probabilities (upper left), the GOES-R Cloud Thickness (upper right), the heritage Brightness temperature difference product and the visible imagery. This is for a case of an extratropical cyclone moving over the northeastern US. The images on this slide are from 0745 UTC on 23 April 2012. Note (Frame 3) how the GOES-R IFR probabilities give more information than the heritage brightness temperature difference product. Surface observations show a large area of IFR conditions in the region where IFR probabilities are high. The IFR probabilities are high both in regions where the satellite signal is strong (the blue circle) and in the red circle where there are multiple water layers. Cloud thickness is diagnosed only in regions where the lowest single layer exists – it is a satellite-only product, whereas the Fog/Low stratus product is a fused product that incorporates both satellite and model data. These images are from 0815 UTC on 23 April 2012. The 0915 UTC image (Frame 4). The traditional BTD product does not detect Fog/Low Stratus over western PA, NY and New England, although it does detect FLS over New Jersey (as does the GOES-R fog/low stratus product). Note the character of the fog/low stratus product over New England – in the red circle. The horizontal homogeneity is characteristic of model prediction of the fog/low stratus. The pixelated region within the blue region is characteristic of a region that is driven by the satellite predictor. Note in this 1045 UTC image (Frame 5) that the sun has risen over New England – IFR probabilities within the red circle have increased – this increase is related to the difference in predictors used during the day compared to night. Note also that the cloud heights have not been computed, as they are not computed during twilight conditions – when the sun is within 10 degrees of the horizon. The 1115 UTC image (Frame 6). The traditional brightness temperature difference is contaminated as the sun rises, as more reflected solar radiation at 3.9 microns is detected by the satellite. The region in the blue area where the BTD product was used to compute fog/low stratus using the GOES-R algorithm is now a region where the model is being used to compute fog/low stratus. You can notice in the animation that the change from night-time – when the BTD product is used – to daytime, when the model is used – is fairly seamless. At 1145 UTC (Frame 7), note that the cloud thickness is starting to be predicted again as the sun rises higher in the sky off the east coast. IFR probabilities continue to be high in regions of a single stratiform cloud layer, and over New England where there are multiple cloud layers. At 1215 UTC (Frame 8) the cloud thickness product expands in coverage as twilight conditions continue to be replaced by daylight.

20. This is a case of advecting stratus over the Texas Pandhandle. On this day a dense fog advisory was discussed by the NWS but never issued although several surface stations had visibilities at ¼ to ½ mile throughout the night. GOES-R IFR probabilities captured the spatial extent of the
stratus deck and showed high probabilities where IFR conditions were reported. The traditional low cloud base product could not identify the regions in the stratus deck that had IFR conditions. That is, it could not distinguish between low stratus and mid-level stratus. Because the GOES-R IFR Probabilities include model data that better represents the surface humidity fields, GOES-R IFR Probability fields can distinguish between the two types of stratus. There is a slide-by-slide animation (Frame 2) of the fields, starting with this 0502 UTC image from 28 February 2012, of GOES-R IFR probabilities (upper left), GOES-R cloud thickness (upper right), Heritage brightness temperature difference fog product (lower left) and heritage low cloud base product (lower right). Frame 3: The stations with IFR conditions are within the red circle, and in fact most of the stations where GOES-IFR probabilities were high reported IFR conditions. None of the stations within the blue circle, where the heritage brightness temperature difference shows fog/low stratus but where the GOES-R IFR probabilities are low, recorded IFR conditions. This image is from 0545 UTC. This 0615 UTC (Frame 4) image has been annotated to show the clear delineation between IFR conditions that are captured will in the GOES-R IFR probability field and the region without IFR conditions. The separation of the two regions is not evident in the traditional products. That separation continues at 0645 UTC (Frame 5) ......and at 0715 UTC (Frame 6) ......and at 0745 UTC (Frame 7) ......and at 0815 UTC (Frame 8)......In this image at 0845 UTC (Frame 9), stations at the edge of the high IFR probabilities (circled in blue) are NOT reporting IFR conditions. Note in the following image that as the GOES-R IFR probability field shows increasing values, IFR conditions start. At 0915 UTC (Frame 10), the stations are still not showing IFR conditions.....nor are they at 0945 UTC (Frame 11) ......nor at 1015 UTC (Frame 12)......nor at 1045 UTC (Frame 13). Note however, how the field of GOES-R IFR probabilities is starting to shift to the north and east, especially over the southern part of the heightened probability field. At 1115 UTC (Frame 14), higher probabilities are knocking on the door of the two southern stations that are circled (note that the surface observations in this figure are from 1100 UTC and the satellite/model based estimators of IFR probabilities are from 1115 UTC. The satellite/model based estimates of IFR probabilities (Frame 15) continue to move northward, and two stations have IFR conditions (the observations are from 1200 UTC). At 1145 UTC (Frame 16), only the northernmost blue circled station remains (1) outside of the higher IFR probabilities as estimated by the GOES-R algorithm and (2) does not report IFR conditions (at 1200 UTC). ...and that continues at 1215 UTC... (Frame 17) By 1232 UTC, the high IFR probability field has moved over the station; at 1300 UTC, that station reports IFR conditions. (Frame 18)

21. This example shows a case of advecting stratus over northern Ohio in early March 2012. This case had a large region over southern Michigan that had ceiling conditions close to – on either side – the IFR criteria of 1000 ft. The stratus deck over Ohio had ceilings well above the IFR criteria – ceilings were mostly higher than 3000 ft – meaning VFR conditions were present. In this case the heritage/traditional brightness temperature difference product could not distinguish between the regions with IFR and VFR conditions. The GOES-R IFR probability product did a much better job. The traditional brightness temperature difference field cannot accurately differentiate between mid-level and low-level stratus. GOES-R IFR Probability fields can because they include model-based information of the lower tropospheric humidity. This
example (Frame 2) will include a series of slides that show GOES-R IFR probabilities (upper left), GOES-R cloud thickness (upper right), Heritage brightness temperature difference fog product (lower left) and heritage low cloud base product (lower right). This first image is from 0702 UTC. Note that the GOES-R products have the highest probabilities north of Ohio. In this 0715 UTC image (Frame 3), GOES-R IFR probabilities exceeding 40% (yellow/orange/red colors in the upper right) overlay stations that reported ceilings between 700 and 1700 feet. Stations within the blue box reported ceilings between 2,000 and 10,000 feet. This image (Frame 4) is from 0745 UTC. The GOES-R Fog/Low Stratus does produce higher probabilities where IFR conditions are not reported (that is, there are false alarms); in those instances, ceilings typically are close to the IFR criteria. The traditional product cannot differentiate between hazardous low stratus and non-hazardous elevated stratus clouds. Continuing with this example (Frame 5), at 0815 UTC… The red line in this image from 0845 UTC (Frame 6) separates the region where GOES-R IFR probabilities show a significantly higher probability of IFR conditions from regions with lower probabilities. Surface observations are consistent with the probabilities; that is, IFR conditions are far more common in the region where the GOES-R IFR probability field is high. That separation (Frame 7) continues at 0915 UTC … and at (Frame 8) 0945 UTC … and at (Frame 9) 1015 UTC … and at 1045 UTC (Frame 10). Throughout this case, the traditional product does a poor job of differentiating between IFR and MVFR/VFR conditions. Only the GOES-R Fog/Low Stratus probability field correctly separates the two regimes because the GOES-R Fused product includes model-based estimates of lower tropospheric humidity.

22. This next example is a radiation fog event over Louisiana on March 6th. Shallow fog developed over Louisiana during the morning of 6 March 2012. AFD mentioned shallow fog formation, and GOES-R IFR probabilities steadily increased hours before the updated AFD (1133 UTC) that mentioned fog as an aviation hazard. The traditional brightness temperature difference product could not accurately discern the areas of fog throughout the event. Slide by slide animations show the pertinent products as seen in AWIPS, starting (Frame 2) with this image at 0432 UTC. The slides show GOES-R IFR probabilities (upper left), GOES-R cloud thickness (upper right), Heritage brightness temperature difference fog product (lower left) and heritage low cloud base product (lower right). The 0545 UTC image (Frame 3) shows an increase in IFR probabilities in southern Louisiana. The Cloud thickness product suggests that any clouds that do form – any fog that is present – is shallow. The traditional fog products appear noisy with no coherent signal. The signal continues to increase at 0645 UTC (Frame 4). At 0745 UTC (Frame 5), the signal is still increasing, and several stations indicate ceilings and visibilities that meet IFR criteria. Fog/Low stratus continues to develop at 0845 UTC (Frame 6). Probabilities increase, cloud thickness increases, the horizontal extent of the higher probabilities increases. And the traditional fog products continue to show a noisy signal with little discernible signal. Trends continue through 0945 UTC (Frame 7) (Note also the signal of cirrus clouds moving in from eastern Texas … more on that below) … and through 1015 UTC (Frame 8) At 1031 UTC (Frame 9), the KLCH AFD mentions the radiational fog along I-10. This is several hours after GOES-R IFR probabilities have suggested that fog might be developing. Fog/Low stratus signals persist in the GOES-R IFR probability field and cloud height fields at 1045 UTC (Frame 10). The GOES-R products give a better representation of the spatial extent of the fog than do the ‘traditional’
products. The same is true at 1115 UTC (Frame 11). The imagery at 1145 UTC (Frame 12) shows the effect of high cirrus on the GOES-R product and on the traditional products (the change in the signal is apparent in Frame 8-11 as well). The GOES-R IFR probability field is not greatly impacted by the cirrus – high probabilities continue to be diagnosed. In contrast, the ‘traditional’ brightness temperature difference product is greatly impacted by the cirrus clouds. The cirrus clouds do prevent cloud thickness from being detected. The product shows the depth of the highest water cloud layer, and a layer of ice clouds interferes with the ability to compute that depth. The GOES-R cloud thickness product can be used to estimate fog dissipation (Frame 13). You should expect thicker clouds to resist dissipation for a longer period of time.

23. This example from 23 March 2012 is also a radiation fog case. Surface stations near the TX coast start reporting IFR conditions at about 0800 UTC; IFR conditions expand to along the Gulf Coast by 1000 UTC. The traditional brightness temperature difference product did depict the area of fog once numerous surface stations reported fog. The BTD method did not capture the extent of the fog event until several hours after the IFR probabilities were high, suggesting widespread fog was present/forming. The slides, such as this one from 0415 UTC (Frame 2), show GOES-R IFR probabilities (upper left), GOES-R Cloud thickness of the highest water cloud (upper right), heritage/traditional brightness temperature difference (lower left) and heritage low cloud base product (lower right). At 0415 UTC, most of the signal/low cloud is over the Gulf of Mexico. At 0445 UTC (Frame 3), the IFR probabilities are increasing over southwestern Louisiana and the central TX Gulf coast. A signal in the cloud depth is also developing. In contrast, the traditional brightness temperature difference product gives no obvious signal of fog in the area. At 0515 UTC (Frame 4), probabilities increase more. Note also that the brightness temperature difference signal is increasing as well, but over a larger geographic area compared to the concentrated region of IFR probability increase. At 0615 UTC (Frame 5), the brightness temperature decrease signal actually wanes, but the GOES-R IFR signal over coastal Texas continues to suggest the presence of fog or low stratus. There are not yet any surface reports of IFR conditions, however. At 0715 UTC (Frame 6), the GOES-R IFR signal persists, caused by rapidly increasing relative humidity. But there are still no surface reports of IFR conditions. IFR conditions are being reported at 0800 UTC (Frame 7) along the Texas Gulf Coast and the 0745 imagery GOES-R IFR probability shows high values in the region of IFR reports. In contrast, the traditional brightness temperature difference field suggests only a small area of fog/low stratus in eastern Texas. So the GOES-R product has given you lead time, highlighting the region where fog will be developing, and it ably delineates the region where fog/low stratus is most likely. A similar tale could be told at 0815 UTC (Frame 8). At 0845 UTC (Frame 9) probabilities increase as more and more surface stations report fog – but the traditional brightness temperature difference field is not capturing the extent of the fog event. At 0915 UTC (Frame 10), the traditional brightness temperature difference product does start to pick up the region of fog / low stratus along the Texas Gulf Coast. The GOES-R IFR product continues to show high probabilities there as well. Similar story at 1015 UTC (Frame 11): the traditional brightness temperature difference product shows a region of fog/low stratus on the coast where the GOES-R IFR probabilities are highest, and where IFR conditions are being reported. Again, the Cloud
thickness product can be used to show where the cloud deck is thickest, which may be related to dissipation. More of the same at 1115 UTC (Frame 12) …and at 1145 UTC (Frame 13).

24. This is a case of Radiation fog in North/South Carolina on 23 March 2012. AFDs suggest the possibility of fog formation, and a dense fog advisory is issued at 1030 UTC. IFR conditions were first reported at 0500 UTC – near the coast. GOES-R Fog/Low Stratus products showed heightened probabilities of IFR conditions well before the traditional brightness temperature difference product detected fog. This 0332 UTC (Frame 2) image shows increased probabilities of Fog / Low stratus (upper left), water cloud thickness (upper right), heritage/traditional brightness temperature difference product (lower left) and Heritage low cloud base product (lower right). The GOES-R fog/low stratus product is already suggesting fog is a distinct possibility, long before a signal appears in the traditional product. Probabilities aren’t especially high at 0415 UTC (Frame 3), but they are noticeably higher along the coast. At 0515 UTC (Frame 4), GOES-R IFR probabilities have increased, especially along the coast, and several stations are reporting IFR conditions. There is also an obvious signal in the highest water cloud thickness product (upper right). In contrast, there is no obvious signal of fog formation in the traditional products. The 0532 UTC image (Frame 5) shows increasing coverage in the GOES-R IFR Probability field, a deepening of the lowest water cloud layer, and a slight increase in the traditional brightness temperature difference-based products……that continues at 0545 UTC (Frame 6). The AFD out of Wilmington NC at this time suggests that fog formation is expected. The GOES-R product has been showing that likelihood of fairly widespread fog whereas the traditional brightness temperature difference field shows only a small region of fog….and these differences in the products continue at 0615 UTC (Frame 7) ……at 0632 UTC (Frame 8)……at 0645 UTC (Frame 9). Note how the IFR conditions appear outside of the region of the traditional brightness temperature difference fog product, but are neatly overlain by the GOES-R IFR probability product. The GOES-R products also show you where the thickest fog is likely to be….and this continues at 0745 UTC (Frame 10) (note how the brightness temperature difference shows fog where the cloud thickness is greatest). But the heritage products do not show the total extent of the fog formation….which continues at 0815 UTC (Frame 11) …..and into 0945 UTC (Frame 12). Note how the heritage/traditional product misses the large extent of fog. There are many stations reporting IFR conditions that lie outside the region of enhanced brightness temperature difference. In contrast, the GOES-R IFR field does a much better job capturing the horizontal extent of the fog field. The final image at 1045 UTC for this case (Frame 13). Bottom line: GOES-R IFR captures the development of the fog before the traditional product, and it more accurately portrays the horizontal extent of the fog field.

25. This next case if of radiation fog over the central Midwest on 13 March 2012. The Des Moines AFD at 0500 UTC suggests patchy fog may occur despite the dry profiles above the surface. The NWS in Lincoln, IL does not mention fog. At 1036 UTC, Des Moines expands the mention of fog development, but only patchy or light fog. At 1100 UTC, Lincoln notes the presence of fog, and calls the nature of the forecast of LIFR ‘challenging’. That’s the backdrop of this particular day. This 0345 UTC (Frame 2) shows increased probabilities of Fog / Low stratus (upper left), water cloud thickness (upper right), heritage/traditional brightness temperature difference product (lower left) and Heritage low cloud base product (lower right). The GOES-R fog/low stratus
The product is already suggesting fog is a distinct possibility, long before a signal appears in the traditional product. The heritage product is showing low clouds/stratus in the Mississippi River valley and over northeast Iowa. The 0402 UTC image (Frame 3) shows smaller probabilities of Fog/Low Stratus over Wisconsin (where ceilings are quite high). The traditional brightness temperature difference shows a strong signal there – model data are de-emphasizing the satellite signal over Wisconsin. This is a benefit of fused data. One source of data can refine the second source to achieve a more accurate result. At 0415 UTC (Frame 4), stray light signals plague all the products (Stray light occurs when the satellite is illuminated by the Sun and the solar signal is detected as emitted radiation). But those stray light effects are temporary and they are gone by 0432 UTC (Frame 5). At 0445 UTC (Frame 6), GOES-R IFR probabilities are starting to increase across the Midwest in a region where the traditional product does not show any fog/stratus signal. By 0615 UTC (Frame 7), IFR probabilities are increasing over the Midwest, and some stations start to report fog/mist with IFR ceilings and visibilities. Note the region over northeast Missouri where the GOES-R IFR probabilities suggest IFR conditions are likely, where the traditional brightness temperature difference does not show a strong signal. This continues at 0645 UTC (Frame 8)......and at 0715 UTC (Frame 9). The new algorithm is doing a better job in showing the development of IFR conditions over northeast Missouri. At 0802 UTC (Frame 10), GOES-R IFR probabilities increase as more stations start to indicate IFR conditions. There is still no clear indication of fog in the traditional products. The development of IFR conditions, and expansion of the GOES-R IFR probability continues through 0845 UTC (Frame 11)......and 0915 UTC (Frame 12)......and 0945 UTC (Frame 13)......and 1015 UTC (Frame 14). Widespread IFR exists over Iowa and northern Missouri in the absence of a clear signal in the traditional satellite-only brightness temperature difference fields. Around 1032 UTC (Frame 15) the NWS in Des Moines posts an AFD mentioning patchy fog to widespread fog. Shortly after, the NWS in Lincoln follows suit. The same relationship between GOES-R IFR probabilities, observed IFR conditions, and the brightness temperature difference persists through 1145 UTC (Frame 16). The traditional products do not accurately portray the horizontal extent of fog and low clouds on this morning. The cloud thickness product can be used to estimate dissipation time. Fog should persist where cloud thickness is greatest.

26. This figure shows the relationship between the last-before-sunrise cloud thickness estimated by the GOES-R algorithms and the number of hours required for the fog to dissipate. The data are for radiation fog only – other types of fogs may advect large distances over time, or they may be sustained by factors other than radiational processes that vary in a predictable way as the sun rises.

27. The following slides show radiation fog dissipating with time. The initial image is at 1102 UTC. GOES-R IFR probabilities are in the upper left, GOES-R Cloud thickness in the upper right, traditional brightness temperature difference product in the lower left, and visible imagery in the lower right. The 1102 UTC image (Frame 2), the last one before twilight conditions invalidate the GOES-R cloud thicknesses, shows maximum thicknesses around 1000 feet in north central Florida/southeastern Georgia. That 1000 feet correlates to a dissipation time of slightly more than 3 hours. Once the sun rises (Frame 3), the radiation fog starts to burn off. (This is the 1245 UTC image) At 1345 UTC (Frame 4), GOES-R cloud thickness suggests that the southern
part of the red circled area is thicker – expect it burn off after the northern half. By 1415 UTC (Frame 5), the fog is fractured and continues to erode from the outsides in. By 1445 UTC (Frame 6), the fog has dissipated, just under 4 hours after the last night time cloud thickness calculation at 1102 UTC. So this example is consistent with the scatterplot that relates cloud thickness to dissipation time.

28. This example from 26 April 2012 in a region with terrain – ceilings were obscured in the Sierra Nevada, but were much higher over the central Valley where elevations were lower. The imagery (Frame 2) in this example includes the IFR probabilities, terrain, heritage (‘traditional’) brightness temperature difference fog product, and visible imagery. This first image is from 1315 UTC. Data at 1345 UTC (Frame 3) show high ceilings over the central Valley, with cloud ceilings between 3000 and 8000 feet above sea level. The 1415 UTC (Frame 4) image shows high IFR probabilities over the region where the terrain rises from the valley floor to the spine of the Sierra Nevada, reaching up to 10000 feet above sea level. The brightness temperature difference (heritage) product shows no signal for these clouds. Similarly, at 1445 UTC (Frame 5), IFR conditions are shown to be likely along the steep slopes of the Sierra Nevada. Valley floor ceilings in the three to 8000 foot range persist.

29. This example highlights the ability of the GOES-R IFR algorithm to track the evolution of the marine clouds that commonly form over the coastal waters of southern California and sometimes drift inland. This example is from 10 May 2012. These slides (Frame 2) will contain the GOES-R IFR probabilities (upper left), GOES-R Cloud depth (upper right), ‘traditional’ or heritage brightness temperature difference fog product (bottom left) and visible imagery (bottom right). This first slide is from 0415 UTC. The 0445 UTC (Frame 3) shows that an oceanic stratus deck is starting to move inland over southern California. GOES-R IFR probability is consistent with surface observations of cloud ceiling. This inland motion continues at 0545 UTC (Frame 4) ...and 0645 UTC (Frame 5)......and 0745 UTC (Frame 6)......and 0845 UTC (Frame 7)......and 0945 UTC (Frame 8)....Note how the traditional brightness temperature difference product shows false positives over inland California starting at this time. This continues at 1045 UTC (Frame 9). Surface observations in this region of false positives do not show IFR conditions. More false positives are present at 1145 UTC (Frame 10). Note also the variability in cloud thickness. Because this is not radiation fog, but is advection fog, the relationship between cloud thickness and ultimate fog dissipation is not robust. This (Frame 11) is the last image available before the sun rises on this scene. So if it *were* radiation fog, the cloud thickness for this scene would relate to the dissipation time. Again, this is radiation fog so the relationship between cloud thickness and dissipation time is not a strong one. The false positive signal in the interior valley of southern CA continue in this image. That signal is missing in the GOES-R Fog/Low Stratus IFR probability image because model data there likely has a surface relative humidity high enough to guide against fog formation. At 1345 UTC (Frame 12), the visible imagery starts to become workable. The GOES-R cloud thickness product is not available during twilight conditions near sunrise and sunset. And the traditional brightness temperature difference field is changed by the addition of reflected 3.9 micrometer radiation from the Sun. The GOES-R IFR product, however, continues to show a strong signal, that is, high probabilities of IFR conditions. At 1445 UTC (Frame 13), the GOES-R Cloud thickness product has resumed being computed as the Sun
climbs higher into the sky. IFR probabilities right along the coast are decreasing, and the cloud thickness product shows low cloud ceilings retreated offshore. There is a signal in the brightness temperature difference field (the traditional ‘fog product’) but the signal is difficult to quantify. At the same time, the visible image shows stratiform clouds persisting inland near the coast. At 1545 UTC (Frame 14), there is continued erosion of the fog/low stratus over coastal southern California…that continues at 1645 UTC (Frame 15) ....and 1745 UTC (Frame 16). By this time, IFR probabilities are low on shore, and the visible imagery shows the cloud bank mostly over water.

30. This example is fog and low stratus associated with an upper level low over Texas. In this case, the utility of the IFR probability is demonstrated for a case with multiple cloud layers. The GOES-R cloud thickness product, however, is available only where single layer boundary layer clouds are present under non-twilight conditions. That is, during the day, or during night, but not in between. These images contain GOES IFR probabilities, GOES-R Cloud thickness, the heritage/traditional Brightness temperature difference product, and the visible satellite imagery. This first image is from 0945 UTC (Frame 2), and it shows fog/low stratus – high probabilities – over much of central Texas. Regions to the east of the high probabilities have modest probability of fog / low stratus. IFR conditions are most common in the region where the GOES-R IFR probability product shows high probabilities. The upper-level low included stratiform clouds (in the blue circle) and cumuliform clouds (in the red polygon). GOES-R IFR probabilities are large in the red region where both model and satellite indicators of IFR are large. The GOES-R Cloud depth product is a satellite-only product – and it is not calculated in regions where multiple cloud layers are present. This is a 1015 UTC image (Frame 3). In the 1115 UTC (Frame 4) imagery, the GOES-R IFR algorithm suggests the presence of IFR conditions within the region of cumuliform clouds – a region where the traditional method (brightness temperature differences) shows no signal. Observations at airports within the region of enhanced IFR probabilities show reduced visibility, but not IFR criteria. At 1215 UTC (Frame 5), twilight conditions prevent the Cloud Thickness product from being produced. The effect of the change in predictors to daytime (right half of image) from nighttime (left half of image) is especially notable over the Texas panhandle (the region is highlighted by a magenta circle). IFR probabilities for this case increase when the daytime predictors are used compared to the nighttime predictors. Note also how the traditional brightness temperature difference product is not yielding a strong signal for fog/low clouds as the sun rises. The 1315 UTC (Frame 6) shows how the GOES-R IFR Probability product continues to provide information – consistent information – as night transitions into day. By 1315 UTC in this case, the solar angle is high enough in the eastern part of the domain that the GOES-R Cloud Thickness is again producing results as well. The visible imagery (lower right) shows the large expanse of clouds associated with this cut-off feature. At 1415 UTC (Frame 7), Cloud thickness once again is diagnosed over the entire domain (for single layer boundary layer clouds) because twilight-type light conditions have passed. Only the GOES-R IFR Probability field is suggesting the possibility of low clouds/fog over Texas. The traditional method, the brightness temperature difference, shows no signal in the region of cumuliform clouds. The entire signal – cumuliform and stratiform – is affected by reflected 3.9 micrometer solar radiation.
31. This example from May 16 2012 shows how the GOES-R IFR product can be used to monitor the Bay Area around San Francisco for IFR conditions. The images (Frame 2) in this example include the GOES-R IFR Probability (upper left), GOES-R Cloud thickness (upper right), the traditional, or heritage, brightness temperature difference fog product (bottom left) and visible imagery (bottom right). Note that the 0415 image of brightness temperature difference has the characteristic error over interior California: too many signal returns in regions where fog/low clouds do not exist. The low stratus moves in (Frame 3) from the Ocean, as suggested by the Cloud Depth, the GOES-R IFR probabilities and the heritage brightness temperature difference products at 0515 UTC...at 0645 UTC (Frame 4) ....and at 0845 UTC (Frame 5). Surface observations around San Francisco Bay show cloud ceilings at or near IFR criteria. This is in a region where the GOES-R IFR probability field shows very high probabilities and the Cloud Thickness is near 1000 feet. At 0945 UTC (Frame 6), IFR conditions continue to press inland. In this 1045 UTC image (Frame 7), and in earlier images – the traditional brightness temperature difference also detects the increase in fog/low stratus over San Francisco Bay; but it also appears to detect – erroneously – fog and low stratus east and southeast of the Bay Area. In that region, the modeled portion of the GOES-R Fog/Low Stratus algorithm downplays the satellite signal of fog and low stratus. In the 1145 UTC image (Frame 8), relatively high GOES-R IFR probabilities overlay stations reporting IFR conditions (in the red circle). GOES-R IFR probabilities are lower in the valley east and southeast of the bay area; in that region, surface stations are reporting VFR conditions (within the blue circle).

32. Jump to page 33. This is a duplicate image.

33. This example shows that GOES-R IFR probabilities are more useful for diagnosing fog formation in the Central Valley of California than are the ‘traditional’ brightness temperature difference products. The images (Frame 2) in this example include the GOES-R IFR Probability (upper left), GOES-R Cloud thickness (upper right), the traditional, or heritage, brightness temperature difference fog product (bottom left) and visible imagery (bottom right). AWIPS difficulties during this event precluded the display of the traditional fog product and the observations, so you may notice that their display differs from that of the GOES-R products. This is a case of radiation fog formation over the central Valley of California. At 0645 UTC (Frame 3), GOES-R products indicate that fog may be forming in the central Valley of California. IFR probabilities are close to 90% in some regions. Surface observations show that ceilings and visibilities are lowering. Fog formation in the southern part of the valley is not indicated in the brightness temperature difference; it does capture the fog in the northern part of the valley...and this continues at 0745 UTC (Frame 4), with the fog in the central part of the southern Central Valley of California suggested in the GOES-R product, but not in the brightness temperature difference field. (Note that portions of the GOES-R IFR probabilities do overlap with brightness temperature difference signals – but only in the west-central part of the Central Valley.....and this continues at 0845 UTC (Frame 5)....and 0945 UTC (Frame 6)......and 1045 UTC (Frame 7)...and 1145 UTC (Frame 8)....and 1245 UTC (Frame 9). At this point the brightness temperature difference signal is becoming a bit more suggestive of fog/low stratus. But this is many hours after the GOES-R IFR Probability field suggested fog was present. This continues at 1345 UTC (Frame 10)...and at 1445 UTC (Frame 11). Note that the thickest regions of fog generally take
the longest to dissipate. Compare this image to the next one, 6 hours later. (Note that the
terminus of the arrows in the figure is the same in this figure and the next). At 2045 UTC (Frame 12),
low stratus persists in regions where the cloud thickness was greatest 6 hours previous.
Note that this relationship may not hold during Tule fog events – the relationship is more
appropriate for radiation fog events such as this one.

34. This example is for a landfalling cyclone over the Pacific Northwest. GOES-R IFR algorithms give
useful information in these cases even when multiple cloud layers are present, as is common
with weather systems. The GOES-R Cloud Thickness product is, however, only available when
single layer boundary layer clouds are present (under non-twilight conditions). The images
(Frame 2) in this example include the GOES-R IFR Probability (upper left), GOES-R Cloud
thickness (upper right), the traditional, or heritage, brightness temperature difference fog
product (bottom left) and visible imagery (bottom right). This first image is from 1045 UTC on 4
June 2012. At 1145 UTC (Frame 3), the storm system includes an area of stratiform clouds
(circled in blue) and an area containing more cumuliform clouds (circled in red). GOES-R IFR
probabilities are highest in the blue circle where model and satellite indicators of IFR conditions
are strong. The traditional brightness temperature difference product has many false alarms
over interior portions of the intermountain west. Note how the traditional brightness
temperature difference product gives very little information over Washington and Oregon in this
1245 UTC (Frame 4) image. GOES-R IFR suggests IFR conditions are possible over western
Oregon, and that is consistent with the surface observations. In this image (Frame 5), the
day/night transition is visible and circled in magenta. IFR probabilities increase as the
terminator passes because of differences in the predictors used during the day compared to
those used at night. Note also that the cloud thickness product is missing in these twilight
conditions at 1315 UTC. After sunrise (Frame 6), when reflected solar radiation degrades the
traditional brightness temperature difference signal, the GOES-R IFR probability nevertheless
has a strong signal in regions where IFR conditions are observed at 1345 UTC. Light conditions
are still close enough to twilight that the Cloud Thickness product is not computed. By 1545 UTC
(Frame 7), the cloud thickness product is once again available – for single layer boundary layer
clouds only. It does not appear where multiple cloud layers are detected, as within the red
circle.

35. GOES-R IFR Probability fields give guidance in Alaska as well. Aviation Tools are especially
important in Alaska because so much travel between isolated towns is done with small planes.
Despite the large pixel sizes associated with GOES Imagery over Alaska, useful information is
produced, as in this example for an extratropical cyclone with multiple cloud layers – a common
occurrence – that makes the fog detection with the traditional brightness temperature
difference product difficult. Also recall that multiple cloud layers will mean that the GOES-R
Cloud thickness product is not produced. These images (Frame 2) include GOES-R IFR
Probabilities (Upper left), GOES-R Cloud Thickness (Upper right), Surface Observations (Lower
Left) and Topography (Lower Right). In this example from 1330 UTC on August 29, 2012, a large
cyclone in the Pacific Ocean is influencing the weather over much of western Alaska. At 1430
UTC (Frame 3), the blue circles indicate regions with single-layer stratiform water clouds. Within
the red polygon are multiple cloud layers, including a cirrus shield. Note how the character of
the GOES-R IFR Probability field in the red polygon, especially over the Ocean, is much smoother than within the blue circles. The pixelated structures within the blue circles are testimony to the satellite data that are being used there. In contrast, the more smoothly varying model fields are dominating in the GOES-R IFR Probability field within the red polygons. IFR Probabilities are higher in regions where both satellite and model data are used as predictors. At 1630 UTC (Frame 4), as the sun rises, several effects are notable. Within the magenta oval is the demarcation line between night-time predictors (west and north) and day-time predictors (east and south). Where twilight conditions occur – within the larger blue circle, for example – GOES-R Cloud thickness is not computed. In the 1730 UTC image (Frame 5), the green oval highlights the divide between GFS model data and Rapid Refresh Model Data. At 1830 UTC (Frame 6), the product continue to provide information, showing a large region of high probability of IFR conditions over western Alaska. By 1930 UTC (Frame 7), after twilight conditions have passed, Cloud Thickness data are once more available in regions with single-layer water clouds.

36. GOES-R IFR Probability can also be used in Alaska – as elsewhere – for guidance when topography ascends up into the clouds. This particular example is for the Brooks Range in northern Alaska. These images (Frame 2) from 1900 UTC on August 29 2012 show GOES-R IFR Probabilities (upper left), Visible Imagery (Lower Left), GOES-R Cloud Thickness (Upper Right) and Topography (Lower right). The GOES-R Cloud Thickness is not computed over northern Alaska in this case (Frame 3) because the clouds there have multiple layers, and the product is available only in regions of single-layer water-based clouds in non-twilight conditions. Note that the Brooks Range (Frame 4) is an east-west oriented mountain range with peaks up to 6000 feet above sea level. GOES-R IFR probabilities align with this terrain feature (Frame 5) – cloud bases in this region become closer and closer to the surface as the topography gets higher and higher.

37. This is a similar example to Page 36, but over southern Alaska. Images (Frame 2) include MODIS-based GOES-R IFR Probabilities (Upper Left), GOES-West-based GOES-R IFR Probabilities (Upper right), the traditional brightness temperature difference product applied to MODIS data (Lower left) and topography (Lower Right). Surface stations in Alaska (Frame 3) are reporting ceilings between 5000 and 10000 feet above sea level. Mountaintops (Frame 4) are well above 6000 feet. GOES-R IFR Probabilities (Frame 5) show higher values over high terrain. Note also that the high-resolution of the MODIS instrument over high latitudes better resolves the effects of terrain. The heritage brightness temperature difference product gives little useful information.

38. AIRMETs over Alaska can be fine-tuned using GOES-R IFR probabilities. GOES data gives better temporal and spatial resolution than surface observations alone. Frame 2 shows the GOES-R IFR Probability that could overlay the AIRMET in Frame 1.

39. The GOES-R IFR product can be used as guidance when creating AIRMETs (Frame 2) for ceiling/visibility obstructions in the lower 48 as well. The GOES-R IFR probability product will depict areas of interest with better spatial and temporal continuity than surface observations alone. (It’s usually a good idea to use both products, of course). The polygons that are created may be more accurately drawn if you use GOES-R IFR boundaries as a guide (Frame 3). The GOES-R IFR Probability is able to identify and delineate – with detail – IFR CIG, IFR BR, IFR PCPN/BR and CLDS/PCPN conditions. The polygon edges can be drawn using the boundaries of
the probability product as a guide. And it works all across the country (Frame 4). GOES-R probability will accurately depict where IFR conditions are existing, and the boundaries drawn will better reflect reality.

40. Data from MODIS on board Terra or Aqua can also be used in the GOES-R Fog/Low Stratus algorithms, with the big benefit of being at a far higher resolution. The 1-km resolution allows very fine-scale features, such as valley fog events, to be captured. GOES-R ABI will have a spatial resolution of 2 km. The disadvantage of MODIS data is poor temporal resolution, as MODIS sits on polar orbiters. MODIS data gives a more detailed depiction of fog events (Frame 2). IFR probabilities and Cloud Thickness fields have small-scale features in the MODIS imagery. The GOES-R products lack the small-scale variability. MODIS gives the better spatial resolution, GOES gives the good temporal resolution. Temporal resolution with ABI will increase from current GOES capabilities, and ABI will have better resolution than current GOES (although not as good as MODIS). Better IFR probabilities arise from the higher MODIS resolution for events such as valley fog. The GOES-based products here miss fine-scale features that MODIS can detect. The next slide will highlight the area within the red box. Valley fogs are detected (Frame 3), or highlighted, better with the good MODIS resolution compared to the coarser GOES resolution. Frame 4 shows a similar event over Pennsylvania. Frame 5 shows a similar case over the Ozarks, and Frame 6 zooms in on the Red Box in Frame 5. MODIS data is better able to capture very small-scale variations in cloud thickness and IFR probability because of the smaller satellite pixel size. A similar case in Canada (Frame 7). Resolution adds to the scene. More small-scale detail in the fog that exists in the small valleys (Frame 8). The final scene (Frame 9) is over southeast Alaska. Here, the pixel size differences between MODIS (1 km) and GOES (5-10 km) is very big.

41. GOES-R FLS Observations compared to other observations over the Atlantic Maritimes. Temporal changes in GOES-R IFR Probabilities correlate well with changes in visibility and ceilings. This is a region where multiple cloud layers are often present, and those layers hamstring the traditional product.

42. To summarize: GOES-R proxy products show more skill (than traditional Brightness temperature difference products) in locating IFR hazards that accompany low clouds at night. The GOES-R products can replace the traditional. There is a day/night discontinuity in the GOES-R products—especially under twilight conditions. Improvements to be made in the near term should mitigate this issue.

43. Work for near-term product improvements focuses on improving daytime results, further validation, testing and improvement of the Low IFR product, and to continue to validate and characterize the overall product performance. Long-term improvements include use of higher-resolution 1-km visible imagery during the day, merge LEO and GEO capabilities, better characterization of landforms (to improve detection/depiction of valley fogs), development of a prognostic IFR/LIFR product and creation of a fog formation alert capability.

44. Additional Training Materials are listed here. In particular, the ‘Fog Blog’—http://fusedfog.ssec.wisc.edu is updated >1/week with new cases/examples.
45. This page lists FAQs. Read them through, and make sure you understand why the answer is what it is. Smoke is not detected with the Fog/Low Stratus product; that is the question most frequently asked.

46. If you have questions or comments, please contact the algorithm developers. Also, there is a ‘Fog Blog’ with many current examples using the GOES-R algorithm:
http://fusedfog.blogspot.com